

# Conferences and Reviews

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## Cardiac Evaluation and Risk Reduction in Patients Undergoing Major Vascular Operations

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Occult coronary artery disease often accompanies symptomatic peripheral vascular disease and has an important effect on survival. Most perioperative and late fatalities after peripheral vascular operations are due to cardiac causes. Noninvasive cardiac testing can identify patients at increased risk for postoperative cardiac complications, although controversy exists regarding the optimal preoperative evaluation. Risk reduction strategies for patients known to be at high risk are also controversial. Some authors advocate coronary revascularization with coronary artery bypass grafting or percutaneous transluminal coronary angioplasty before the vascular procedure. Others believe that the combined morbidity and mortality of 2 operations exceed those of a peripheral vascular operation performed with aggressive monitoring and medical therapy. Continuous electrocardiographic monitoring after an operation has identified silent myocardial ischemia as a powerful predictor of cardiac complications. Ongoing research is likely to provide insights into the pathogenesis of postoperative cardiac complications and may lead to specific therapeutic interventions. Few prospective studies have been done in this area, and the threshold for preoperative and postoperative intervention is unknown. I review the literature and present an algorithm to guide cardiac testing and risk reduction in patients undergoing elective vascular surgical procedures.

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Atherosclerosis has a direct pathogenic role in occlusive peripheral vascular disease and an indirect role in the development of vascular aneurysms.<sup>1</sup> Atherosclerosis is a diffuse process, and patients with peripheral vascular disease often have coronary artery disease. These patients frequently do not have symptoms of coronary ischemia because their lower extremity claudication limits exercise tolerance and prevents them from attaining cardiac stress levels that provoke ischemia. Therefore, preoperative cardiac assessment in this high-risk group can be difficult. In this article I review the relationship between coronary artery and peripheral vascular disease, noninvasive cardiac testing to identify patients at high risk for postoperative complications, and strategies that may decrease the incidence of cardiac complications following peripheral vascular operations.

### Relationship Between Coronary Artery Disease and Peripheral Vascular Disease

To define the relationship between coronary artery disease and peripheral vascular disease, 1,000 patients being considered for peripheral vascular reconstruction at the Cleveland (Ohio) Clinic underwent preoperative coronary angiography. Coronary artery disease was surprisingly common; only 14% of those studied had normal

coronary arteries. Patients clinically suspected of having coronary artery disease had a 78% incidence of "severe" coronary occlusion (greater than 70% stenosis of at least 1 vessel). Patients with no clinical evidence of heart disease had a 49% incidence of "moderate" coronary artery disease (stenoses of as much as 70%) and a 37% incidence of "severe" disease.<sup>2,4</sup> Several other studies have correlated coronary angiographic findings with different types of peripheral vascular disease. Patients with abdominal aortic aneurysms have a 52% to 82% incidence of severe coronary artery disease (75% to 100% occlusion of a major vessel), and those with peripheral occlusive disease have a 47% to 60% incidence of severe coronary artery disease. Many of these patients had no clinical evidence of cardiac disease, and 30% of those with severe coronary disease had normal electrocardiograms.<sup>5,6</sup> The high prevalence of occult coronary artery disease accounts for a substantial portion of both early and late postoperative deaths. Among patients undergoing resection of an abdominal aortic aneurysm and aortoiliac reconstruction, early deaths due to cardiac causes occur in 45% and 67%, respectively. Long-term follow-up reveals that cardiac disease is also responsible for 38% to 55% of late deaths in both groups.<sup>7,8</sup> A recent study in which a fifth of patients leaving the hospital after a vascular oper-

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**ABBREVIATIONS USED IN TEXT**

CABG = coronary artery bypass grafting  
 CASS = Coronary Artery Surgery Study  
 MI = myocardial infarction  
 PTCA = percutaneous transluminal coronary angioplasty

ation had cardiac complications within the next two years emphasizes these long-term cardiac complications.<sup>9\*</sup> This is consistent with the 20% cardiac mortality over 11 years reported earlier.<sup>7</sup>

### Cardiac Risk Assessment With Noninvasive Cardiac Testing

Cardiac risk stratification to identify patients at increased risk for postoperative complications is imperative before major vascular procedures. Preoperative cardiac catheterization is too invasive and expensive to be used in the initial assessment. The use of risk stratification based solely on clinical risk factors, such as the Goldman Multifactorial Index, has been advocated, but several studies show that these assessments may underestimate the incidence of cardiac complications after vascular surgical procedures.<sup>10-15</sup> Routine exercise treadmill testing is suboptimal because claudication limits exercise tolerance, resulting in inadequate stress levels and nondiagnostic studies.<sup>16-17</sup> Therefore, there has been a search for noninvasive techniques capable of identifying high-risk patients who may benefit from further invasive diagnostic studies and possible revascularization.

Measuring the left ventricular ejection fraction has been proposed as a method to identify high-risk patients undergoing vascular operations. As a functional assessment, the ejection fraction was thought to predict how well the heart could withstand the stresses of aortic cross-clamping and unclamping. In a 1985 study, patients with ejection fractions greater than 55% were reported to be at low risk for postoperative myocardial infarction (MI), whereas those with ejection fractions of less than 35% had a 75% incidence of postoperative MI.<sup>18</sup> More recent studies have shown that patients with ejection fractions of less than 35% can undergo a major vascular operation with acceptable 30-day mortality, while others have shown no correlation between the ejection fraction and the incidence of postoperative MI.<sup>19-21</sup> Prospective studies comparing ejection fraction determinations with dipyridamole-thallium imaging before aortic operations have shown ejection fractions to be inferior in predicting postoperative cardiac events.<sup>14,22</sup> Thus, the ejection fraction should not be used as the primary tool to identify high-risk patients before vascular procedures. The ejection fraction can, however, be used as an adjunct in the evaluation of certain patients. For instance, patients with ejection fractions of less than 30% are at risk for congestive heart failure, have limited survival, and should undergo a major vascular surgical procedure in only the most dire circumstances.

Using continuous electrocardiographic monitoring, several studies have documented a high frequency of perioperative myocardial ischemia. In patients with peripheral vascular disease, preoperative myocardial ischemia is predictive of postoperative cardiac events.<sup>23,24</sup> In one study, patients with preoperative ischemia had a 38% incidence of postoperative cardiac events whereas those with no preoperative ischemia had a 0.7% incidence of postoperative cardiac complications.<sup>23</sup> Other investigators examining the incidence of both preoperative and postoperative ischemia have found that postoperative myocardial ischemia is more strongly predictive of postoperative clinical events.<sup>25,26</sup>

Many authorities regard dipyridamole-thallium scintigraphy as the best test to predict adverse cardiac events in patients undergoing vascular operations. Dipyridamole induces coronary vasodilation, dilating normal vessels to a greater extent than atherosclerotic vessels, creating a coronary steal syndrome. Two images showing myocardial thallium distribution are compared: one immediately after dipyridamole is administered and the second hours later. A fixed defect—seen on the first image and persisting on the delayed image—is indicative of nonviable myocardium, usually the result of infarction. Thallium redistribution—a defect on the first image that fills in on the delayed image—is a marker for hypoperfused viable myocardium. The finding of thallium redistribution is associated with postoperative cardiac complications.

Dipyridamole-thallium scans were done on 48 patients with suspected stable coronary disease who were undergoing vascular operations. Eight of these patients (17%) had postoperative cardiac ischemic events. When comparing the dipyridamole-thallium results with clinical variables, the scan was the best predictor of postoperative myocardial infarctions. Patients with thallium redistribution had a 50% incidence of cardiac events, but no such events occurred in patients whose scans were normal or showed persistent defects.<sup>27</sup> In another study, preoperative dipyridamole-thallium scans were taken of 116 patients referred for aortic reconstruction. In all, 54 patients showed evidence of thallium redistribution; of these, 9 (17%) had postoperative myocardial infarctions. None of the 62 patients with normal studies or persistent defects had postoperative myocardial infarction or cardiac death.<sup>28</sup> Recent studies, however, have questioned the usefulness of preoperative dipyridamole-thallium scans. In one study, a 40% incidence of cardiac complications and 6% mortality were reported in patients whose preoperative scan showed fixed defects. Further stratification of patients with fixed defects has been advocated by obtaining a delayed image four hours after the second scan. If the fixed defect subsequently fills in, the patient would be considered to be at increased risk for cardiac complications.<sup>14</sup> In another study of 60 patients undergoing elective vascular operations, each patient had preoperative dipyridamole scans, postoperative monitoring with continuous electrocardiography, and postoperative clinical assessment. There was no association between thallium redistribution and the incidence of perioperative ischemia or

\*See also the editorial by D. T. Mangano, PhD, MD, "Perioperative Cardiac Morbidity—Epidemiology, Costs, Problems, and Solutions," on pages 87-89 of this issue.

adverse cardiac outcomes. The sensitivity and specificity of dipyridamole-thallium scans for clinical events were 46% and 66%, respectively.<sup>29</sup> Quantitative dipyridamole imaging has been reported to identify high-risk patients more accurately, although this technique is not widely used.<sup>30-32</sup>

Despite these conflicting reports, dipyridamole-thallium scintigraphy is the most commonly used tool to assess cardiac risk before a peripheral vascular operation. Several questions have been raised regarding the use of these scans: Should every patient have a dipyridamole scan before surgical therapy? and Can scan performance be improved through better patient selection?<sup>33</sup> A retrospective analysis found five clinical factors that enhanced the predictive value of dipyridamole scans: age greater than 70 years, a history of angina, the presence of diabetes mellitus, Q waves on the resting electrocardiogram, and a history of ventricular arrhythmias. Patients with none of these clinical risk factors had a 3% incidence of cardiac complications after a major vascular procedure. Patients with three or more risk factors had a 50% incidence of postoperative cardiac events. Even patients with three or more risk factors whose scans were normal had a 30% incidence of postoperative complications. The scan was most discriminating in patients with one or two risk factors. In this group a normal scan or a fixed defect was associated with a 3% incidence of cardiac events, whereas thallium redistribution was associated with a 30% incidence of postoperative events. It was recommended that only patients with one or two clinical risk factors have preoperative dipyridamole-thallium scans. Those with no clinical risk factors were thought to be at low risk and to be able to proceed directly to surgical therapy. Those with three or more risk factors should be considered to be at increased risk for postoperative cardiac events and should be considered for further workup.<sup>34</sup> There are currently no prospective studies reporting the selective use of dipyridamole-thallium scans. A retrospective series of 200 elective aortic reconstructions was reported in which thallium scans were ordered at the discretion of the referring physician or surgeon. Preoperative scans were done in 29%, prompting coronary angiograms in 11% and coronary revascularization in 9%. These interventions resulted in an operative mortality of 2% and cardiac morbidity of 4%.<sup>35</sup> Based on the available data, a selective approach to screening patients seems reasonable, but validation with prospective studies is necessary.

Some institutions have replaced dipyridamole-thallium scans with adenosine-thallium scans, dipyridamole-sestamibi scans, or dipyridamole or dobutamine echocardiography. Adenosine is a short-acting coronary vasodilator that has fewer side effects than dipyridamole.<sup>36</sup> Adenosine-thallium scanning has been shown to be equivalent to exercise thallium scintigraphy in the diagnosis of coronary artery disease, but it has not been compared with dipyridamole-thallium scanning.<sup>37</sup> Technetium Tc 99m sestamibi is a new myocardial perfusion agent that offers superior quality images when compared with the use of thallium and also adds additional informa-

tion with simultaneous ejection fraction determinations. Data suggest that <sup>99m</sup>Tc-sestamibi will be useful when combined with either dipyridamole or adenosine.<sup>38</sup> Dipyridamole and dobutamine echocardiography have also been reported to identify patients at increased risk for cardiac complications.<sup>39,40</sup> Arm exercise coupled with thallium imaging can also diagnose coronary artery disease in patients with peripheral vascular disease.<sup>41</sup> These techniques require further study before their routine use is recommended.

### Strategies to Decrease Postoperative Cardiac Complications

The diagnostic studies discussed earlier permit the identification of patients at increased risk for perioperative cardiac events when undergoing major vascular operations. Once a patient is determined to be at high risk, risk reduction strategies should be considered. The options for reducing risk include a coronary artery bypass grafting (CABG) operation before the vascular procedure, percutaneous transluminal coronary angioplasty (PTCA) before the vascular procedure, or aggressive monitoring directing medical interventions before, during, and after the operation. Few prospective data are available in this area.

Several authors have reported minimal complications in patients who have undergone a CABG procedure and then later were seen for a noncardiac operation (Table 1).<sup>42-51</sup> A total of 1,600 patients enrolled in the Coronary Artery Surgery Study (CASS) registry, who subsequently required noncardiac operations, were analyzed. Patients were separated into three groups based on their coronary angiograms and their subsequent treatment: patients without substantial coronary artery disease, those with coronary disease who underwent CABG, and those with notable coronary artery disease who were managed with medical therapy. Surgical mortality following noncardiac operations was then determined for each group. Patients without coronary artery disease had an operative mortality of 0.5%. Patients with considerable coronary occlusions who had CABG before the noncardiac procedure had an operative mortality of 0.9%, and those patients with coronary artery disease who received medical therapy had an operative mortality of 2.4%.<sup>44</sup> In another study 60 patients with previous CABG who later presented for major surgical therapy were reported; there were no perioperative deaths and only 8 transient arrhythmias.<sup>52</sup> These studies reflect noncardiac operative mortality that is considerably lower than that associated with vascular operations. A 1.6% mortality was reported after aortic aneurysm repair in patients who had previously undergone bypass grafting, whereas patients without previous CABG had a 4.8% mortality.<sup>45</sup> Other groups have reported no mortality and no postoperative MIs in patients who had CABG before major vascular operations.<sup>43,53</sup>

These results are often cited as arguments in favor of recommending CABG before vascular operations to decrease perioperative cardiac complications. These studies, however, do not address the value of CABG because of their inherent selection bias. Patients were enrolled in

TABLE 1.—Operative Mortality With and Without Specific Interventions

| Source                            | Patients, No. | Population                                     | Intervention                                   | Mortality, % |
|-----------------------------------|---------------|--|--|--------------|
| Gersh et al, 1983 <sup>42</sup>   | 1,086         | <65 years old                                  | CABG alone                                     | 1.9          |
|                                   |               | >65 years old                                  | CABG alone                                     | 5.2          |
|                                   |               | >75 years old                                  | CABG alone                                     | 9.5          |
| Toal et al, 1984 <sup>43</sup>    | 224           | Peripheral vascular disease                    | CABG alone                                     | 6            |
| Foster et al, 1986 <sup>44</sup>  | 1,600         | Without CAD                                    | None, NCS                                      | 0.5          |
|                                   |               | With CAD                                       | NCS with previous CABG                         | 0.9*         |
|                                   |               | With CAD                                       | NCS with medical therapy                       | 2.4*         |
| Young et al, 1986 <sup>45</sup>   | 302           | Peripheral vascular disease                    | CABG alone                                     | 6            |
|                                   |               |  | Abdominal aortic surgery with previous CABG    | 1.6*         |
|                                   |               |  | Abdominal aortic surgery without previous CABG | 4.8*         |
| Isacson et al, 1990 <sup>46</sup> | 40            | Abdominal aortic surgery                       | Central venous pressure monitoring             | 0†           |
|                                   |               |  | PCWP monitoring                                | 2†           |
| Mullany et al, 1990 <sup>47</sup> | 159           | >80 years old                                  | CABG alone                                     | 10           |
|                                   |               | >80 years old with peripheral vascular disease | CABG alone                                     | 17           |
| Allen et al, 1991 <sup>48</sup>   | 148           | With CAD                                       | NCS with previous PTCA                         | 1*           |
| Berlaak et al, 1991 <sup>49</sup> | 89            | Vascular surgery                               | Central venous pressure monitoring             | 9.5          |
|                                   |               |  | PCWP monitoring                                | 1.5          |
| Taylor et al, 1991 <sup>50</sup>  | 491           | Vascular surgery                               | 5% underwent preoperative cardiac evaluation   | 2.2          |
| Huber et al, 1992 <sup>51</sup>   | 50            | With CAD                                       | NCS with previous PTCA                         | 1.9*         |

CABG = coronary artery bypass surgery, CAD = coronary artery disease, NCS = noncardiac surgery, PCWP = pulmonary capillary wedge pressure, PTCA = percutaneous transluminal coronary angioplasty

\*Mortality of the noncardiac operation, not including mortality of the intervention. †Not statistically significant.

these studies when they presented for their second surgical procedure. All patients had survived their CABG and were considered candidates for a second major operation. If CABG is recommended specifically to decrease the incidence of surgical complications, the morbidity and mortality of CABG should be included in the overall morbidity and mortality. A "prophylactic CABG" is done specifically to decrease postoperative complications and must be contrasted to a CABG done for indications that have shown survival benefit.<sup>54</sup>

Several reports document that patients with peripheral vascular disease have increased morbidity and mortality after CABG. The mean age of patients undergoing peripheral vascular operations is 65 years, and the CASS data have shown that CABG in this age group is associated with an increased number of complications. Mortality after CABG was 5.2% in patients older than 65 years, compared with 1.9% in younger patients. Mortality increased further to 9.5% in patients older than 75 years. Although morbidity was not reported, older patients had substantially longer hospital stays than younger patients.<sup>42,55</sup> Other studies have confirmed these results. In two separate reports, 6% CABG mortality rates were noted for patients with peripheral vascular disease.<sup>43,45</sup> Mortality from CABG in patients older than 80 years is 10% and increases to 17% in the presence of peripheral vascular disease.<sup>47</sup> Clearly patients with peripheral vascular disease are at greater risk for complications after CABG than other populations.

When considering prophylactic revascularization before a vascular operation, the cumulative morbidity and mortality must be examined. There are no prospective data, and historical information is difficult to interpret because of differences in patient populations and reported outcomes. Recognizing these limitations, the above data indicate that prophylactic CABG may increase overall

mortality. Coronary bypass surgery in patients with peripheral vascular disease carries a 6% mortality, followed by vascular surgery with as high as 1.6% mortality (after CABG), resulting in 7.6% mortality. This figure is much higher than the 4.8% mortality in patients with documented coronary atherosclerosis who did not undergo CABG before a vascular procedure.<sup>43,45</sup> Therefore, in the absence of prospective data, information obtained by combining studies indicates that prophylactic CABG may increase rather than decrease mortality after a major vascular operation.

Percutaneous transluminal coronary angioplasty has been advocated as an alternative to CABG. It is associated with less morbidity and mortality than CABG, and its use has been advocated before major surgical procedures if substantial coronary artery disease is found. This recommendation is based on anecdotal experience because there is little information addressing the efficacy of PTCA before noncardiac operations. One report included 148 patients who underwent PTCA and later required noncardiac procedures. One cardiac death and seven ischemic events were reported in the postoperative period for an overall cardiac morbidity of 11%.<sup>48</sup> The Mayo Clinic (Rochester, Minnesota) reported a retrospective uncontrolled series of 55 patients who had PTCA before a noncardiac operation in an effort to diminish postoperative cardiac morbidity. Their postoperative myocardial infarction rate was 5.6%, and postoperative mortality was 1.9%.<sup>51</sup> The postoperative mortality of 1.9% may not be substantially different from the 2.4% mortality in patients undergoing noncardiac operations without previous revascularization.<sup>44</sup> The PTCA studies are retrospective and without control groups, so it is difficult to assess the effect prophylactic PTCA has on postoperative cardiac complications.

Efforts to decrease postoperative cardiac complica-

tions have recently shifted from preoperative revascularization to postoperative monitoring and aggressive medical therapy. The Perioperative Ischemia Research Group used continuous electrocardiographic monitoring before, during, and after noncardiac operations to study myocardial ischemia. The incidence of myocardial ischemia was 20% preoperatively, 25% intraoperatively, and 41% postoperatively. Postoperative myocardial ischemia had the strongest univariate association and the only multivariate association with clinical cardiac events. Although controversy exists regarding the relative importance of preoperative and postoperative ischemia, several reports have confirmed the strong association between postoperative ischemia and clinical cardiac complications.<sup>25,56-58</sup> Postoperative ischemia occurs within the first 48 hours after a surgical procedure and is more severe than ischemia detected during other periods. Postoperative myocardial ischemia is clinically silent more than 90% of the time, is not associated with tachycardia, and follows a circadian rhythm with most ischemic events occurring in the early morning hours.<sup>25,26,59,60</sup> One group has reported the presence of myocardial ischemia for 53 minutes before each clinical event.<sup>24</sup> Thus, monitoring high-risk patients for 48 hours may allow interventions that decrease the severity of ischemia. The physiology of postoperative myocardial ischemia is not well understood, but it does not appear to be a simple supply-and-demand phenomenon. Therefore, it is unclear which interventions will decrease the amount of ischemia and whether these interventions will translate into fewer clinical events. There have been preliminary reports that  $\beta$ -blockade and high-dose narcotic analgesia can decrease the postoperative ischemic burden.<sup>61-63</sup> These results are preliminary, and ongoing research is likely to provide further insights into postoperative myocardial ischemia—its pathogenesis, prevention, and treatment.

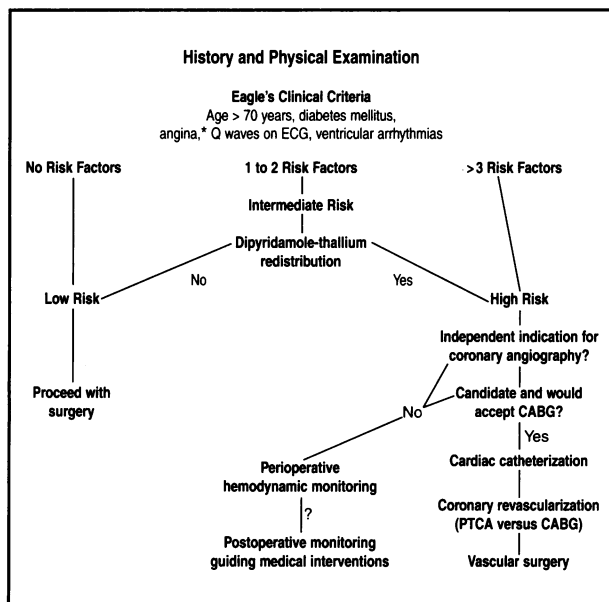
Even without specific postoperative interventions, several studies have reported decreasing mortality—on the order of 2%—after abdominal aortic aneurysm repair.<sup>50,64,65</sup> In addition, there are data supporting further declines in operative mortality when hemodynamic monitoring is used.<sup>66,67</sup> A recent prospective, randomized study used pulmonary artery catheters to test the hypothesis that preoperative “hemodynamic optimization” would result in fewer perioperative complications after peripheral vascular operations. Patients whose hemodynamic parameters were manipulated to obtain a normal cardiac index, pulmonary artery wedge pressure, and systemic vascular resistance before the surgical procedure were compared with a control group without invasive hemodynamic monitoring. The pulmonary artery catheter group had fewer adverse intraoperative events, less postoperative morbidity, fewer early graft thromboses, and fewer deaths. The overall complication rate was 16% in the pulmonary artery catheter group and 43% in the control group. No differences were detected between patients whose pulmonary artery catheter was placed 12 or 3 hours preoperatively, so the duration of preoperative optimization was not a factor.<sup>49</sup> Another group inserted pulmonary artery catheters preoperatively and then determined filling pres-

ures that produced optimal left ventricular performance for each patient undergoing aortic aneurysm repair. The pulmonary artery wedge pressure was maintained at this optimum value during and after the operation. Using this protocol, the authors reported a hospital mortality of 0.9%, although there was no control group in this study.<sup>68</sup> These reports support earlier data indicating that aggressive hemodynamic monitoring in high-risk patients results in fewer cardiac complications.<sup>69</sup> Other data, however, leave this conclusion questionable. Patients undergoing abdominal aortic procedures have been randomly assigned to central venous pressure or pulmonary artery catheter monitoring. Two studies showed no differences in morbidity or mortality between these two modalities. Both of these studies included small numbers and enrolled only low-risk patients.<sup>46,70</sup> Pulmonary artery catheter monitoring may be beneficial when higher risk patients are included. Previous studies have shown that changes in pulmonary capillary wedge pressure are not always reflected by changes in the central venous pressure during aortic operations. Clinical variables could not identify those patients in whom the central venous pressure and pulmonary capillary wedge pressure were discordant. It was concluded that there was no substitute for measuring the pulmonary capillary wedge pressure.<sup>71</sup> The risks and benefits of pulmonary artery catheterization in surgical patients were addressed, and it was found that pulmonary artery catheter monitoring provided useful information while exposing patients to minimal risks.<sup>72</sup> Thus, pulmonary artery monitoring may not be necessary in low-risk patients, but has the potential to decrease morbidity and mortality in high-risk patients. Again, randomized prospective studies are needed.

## Summary

Coronary artery disease often accompanies peripheral vascular disease and exerts an adverse effect on surgical outcome. Dipyridamole-thallium scintigraphy is currently the most widely used noninvasive technique for identifying high-risk patients before a surgical procedure, though it will be replaced by other techniques in the future. The management of high-risk patients remains controversial because of a lack of prospective data. The threshold for intervening with revascularization is not defined, but “consideration for vascular surgery alone is not an indication for coronary revascularization.”<sup>75(p210)</sup> Revascularization should be considered, however, for patients in whom long-term benefit has been demonstrated.<sup>54</sup>

Based on the preceding literature review, the following modification of Wong and Detsky's approach to patients undergoing elective vascular surgical procedures is recommended (Figure 1).<sup>73</sup> Patients should have a complete history and physical examination. Eagle's clinical criteria—older than 70 years, history of angina, the presence of Q waves on the electrocardiogram, history of ventricular arrhythmias, and diabetes mellitus—can then provide guidelines for further evaluation. Because the evaluation of angina in patients with peripheral vascular disease remains problematic, only those patients able to walk two blocks at



**Figure 1.**—The schema shows the cardiac evaluation and risk reduction before major vascular surgical procedures (modified from Wong and Detsky<sup>73</sup>). CABG = coronary artery bypass grafting, ECG = electrocardiogram, PTCA = percutaneous transluminal coronary angioplasty, \* = patients unable to walk 2 blocks at a normal pace should not be considered free of angina

a normal pace (Canadian Cardiovascular Society Angina Class II or better) should be considered free of angina.<sup>12,74</sup> Patients with none of Eagle's risk factors are considered at low risk and may proceed directly to surgical treatment. Patients with one or two clinical risk factors are considered at intermediate risk and should undergo dipyridamole-thallium scintigraphy. Those with no evidence of thallium redistribution are considered at low risk and may undergo an operation. Patients whose scans show redistribution and those with three or more clinical risk factors are considered to be at high risk for cardiac complications. Because prophylactic CABG may increase morbidity and mortality and preoperative PTCA is of unproven value, most of these high-risk patients can be managed medically without preoperative revascularization. Invasive cardiac evaluation should be limited to patients with independent indications for coronary angiography and to those who are candidates and are willing to undergo CABG before their vascular procedure. Patients identified as high risk should have a pulmonary artery catheter inserted and should have normal hemodynamic values before their operation. Every effort should be made to maintain values within the normal or optimal range during the intraoperative and postoperative periods. Clinicians should be aware of the high incidence of silent postoperative myocardial ischemia and its implications. Interventions such as patient-controlled analgesia and  $\beta$ -blockade may reduce the incidence of postoperative cardiac complications, but there are no data yet available to support their routine use.

Coronary artery disease has a profound adverse effect on the long-term survival of patients with peripheral vascular disease. All of these patients should be considered

to have lifelong risks for cardiac complications and should be observed closely.

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